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OPTICAL FIBER
[Hikari faiba]

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Specification

1. Name of this Invention

OPTICAL FIBER

2. Claims

Plastic optical fiber having a core-sheath structure, wherein the core element is made of a transparent material, and the sheath part comprises a polymer mainly (1) consisting of methacrylic acid ester containing cyclic hydrocarbon groups having at least 6 carbons in the ester section and (2) having a refraction factor that is at least 0.01 below the refraction factor of the material forming the core element.

3. Detailed Explanation of this Invention

[Field of the Invention]

The present invention relates to a plastic optical fiber that can be utilized as the core wire of optical fiber, optical fiber cord, or optical fiber cable.

[Conventional Technology]

Although a photo transmission fiber comprising a plastic core is less effective in preventing photo transmission loss and heat resistance compared with the inorganic glass material, it has advantages, such as large opening diameter, lightweight, and excellent sintering characteristic. Particularly, among those photo transmission fibers, photo transmission fibers comprising a core

element made of a polymethyl methacrylate type resin are utilized for short distance optical communications.

Selecting a sheath component material capable of drawing the most effective use of core component is critical to the photo transmission fibers of core-sheath structure.

Pat. No. 53-21660 disclosed a photo transmission fiber comprising a sheath part made of a copolymer of fluoro vinylidene and tetrafluoroethylene.

The drawback of this technique is that, although the fluoro vinylidene type copolymer has excellent adhesiveness to the core material and satisfactory processibility, as the material essentially consists of crystal high molecules, when heated or cooled, the material is easily crystallized to cause spherical crystal growth. As a result, a light that passes the core material is diffused by the crystallized sheath, subsequently reducing the photo transmission capacity.

Pat. No. 56-8321 disclosed a photo fiber comprising a sheath part made of a polymer mainly consisting of fluoro alkyl methacrylate. Although this polymer essentially consisting of non-crystal high molecules can provide excellent transparency when used as the sheath part of the fiber, the adhesiveness to the core material, winding resilience, and processibility are insufficient.

[Problems to Be Solved by this Invention]

As described above, each of the conventional sheath part of optical fiber has benefits and drawbacks, requiring further improvements. The developers of the present invention investigated a new composition for providing an optical fiber comprising a sheath part having excellent adhesiveness to the core material, winding resilience, processibility, heat resistance, as well as the transparency and photo transmission capacity, and have completed the present invention.

[Method to Solve the Problems]

To achieve the object as described above, the present invention provides a plastic optical fiber having a core-sheath structure, wherein the core element comprises a transparent material, and the sheath part is made of a polymer mainly consisting of methacrylic acid ester containing cyclic hydrocarbon groups having at least 6 carbons at the ester part and having a refraction factor that is at least 0.01 below the refraction factor of the core element forming material. The optical fiber prepared in this manner can provide far improved winding resilience, processibility, and heat resistance compared with the conventional plastic type optical fiber.

Examples of methacrylic acid ester comprising the ester part having cyclic hydrocarbon groups containing at least 6 carbons, being used as a polymer for forming the sheath part of this invention, are methacrylic acid cyclohexyl, methacrylic acid cyclopentyl,

methacrylic acid -1-adamantyl, methacrylic acid -2-adamantyl, methacrylic acid -5,5-dimethyl-1-adamantyl, methacrylic acid-3-ethyl-1-adamantyl, methacrylic acid-3-methyl-5 ethyl-1-adamantyl, methacrylic acid-5,5,8-triethyl adamantly, methacrylic acid-3,5-dimethyl-8-ethyl-1-adamantyl, methacrylic acid bornyl, methacrylic acid isobornyl, methacrylic acid-p-methane, methacrylic acid-2-methyl camphene, methacrylic acid 2,2,5-trimethyl cyclohexyl, methacrylic acid tricyclo [5,2,1,0^{2,6}]-deca-8-il, methacrylic acid octa hydro-4,7-mentanoindene-5-il, methacrylic acid octahydro-4,7-mentanoindene-1-ilmethyl, methacrylic acid-2,6,6-trimethyl-bicyclo [3,1,1] heptane-3-il, and methacrylic acid 3,7,7-trimethyl bicyclo [4,1,0] heptane-4-il. Other copolymer components composing a copolymer with those methacrylic acid cyclic alkyl esters are chained alkyl methacrylate, fluoro alkyl methacrylate, di (fluoro alkyl) fumalate, and methacrylic acid.

Practical examples of chained alkyl methacrylate are methacrylic acid methyl, methacrylic acid ethyl, methacrylic acid n-propyl, methacrylic acid iso-propyl, methacrylic acid n-butyl, and methacrylic acid sec-butyl.

Practical examples of fluoro alkyl methacrylate are methacrylic acid 2,2,2-trifluoro ethyl, methacrylic acid 2,2,3,3,3-pentafluoro propyl, methacrylic acid 1,1,1,3,3,3-hexafluoro-2-propyl, methacrylic acid perfluoro isopropyl, methacrylic acid 2,2,3,3-tetra fluoro propyl, methacrylic acid 2,2,3,4,4-hexafluorobutyl, methacrylic acid

1,1,5-trihydroperfluoro pentyl, methacrylic acid 1,1,2,2-tetrahydroperfluoro octyl, and methacrylic acid 1,1,2,2-tetrahydroperfluoro decyl.

The polymer forming the sheath part of the present invention can be produced by any applicable conventional method, such as suspension polymerization, solution polymerization, or block polymerization.

Examples of radical polymer initiator used for this polymer are azo compounds, such as 2,2'-azobis (isobutylonitryl), 1,1'-azobis (cyclohexane carbonitryl), 2,2'-azobis (2,4-dimethyl valeronitryl), azobis isobutanol diacetate, and azo-tert-butane, and organic peroxides, such as di-tert-butyl peroxide, dicumyl peroxide, di-tert-butyl perfuthalate, di-tert-butyl peracetate, and di-tert-alumi peroxide. As for the amount of polymerization initiator, the amount should be preferably adjusted to satisfy a ratio of 0.001 - 1 mol% of the total amount of monomers.

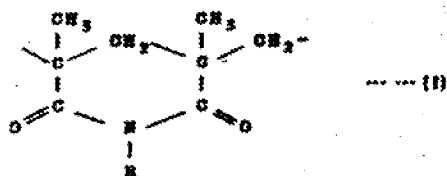
In addition, in order to control the molecular weight in the polymer system, materials, such as tert-butyl mercaptan, n-octyl mercaptan, or n-dodecyl mercaptan, is added as a chain transfer agent. In this case, an amount of such agent should be approx. 1 mol% or less of the total amount of monomers.

The refraction factor of the polymer forming the sheath part is preferably at least 0.01 lower than the refraction factor of the core-forming polymer.

The core of the optical fiber of the present invention may be made of an inorganic material, such as multi-component glass or quartz glass, or it may be made of a clear organic high molecular weight material represented by the materials, such as polymethyl methacrylate type resin polystyrene type resin, polycarbonate type resin, poly-4-methyl pentene-1, or deuteride of polymethyl methacrylate or polystyrene. The polymethyl methacrylate type resin is particularly preferred among those clear organic high molecular weight materials for obtaining effective photo transmission capacity. In this case, the copolymer may comprises the polymethyl methacrylate units or methyl methacrylate units as the main component of the copolymer, preferably at least 70 wt% of copolymer composition, or a resin created by deuteride-processing this copolymer may be used. Examples of components copolymerized with methyl methacrylate are acrylic acid esters, such as methyl acrylate, ethyl acrylate, propyl acrylate, butyl acrylate, or 2-ethyl hexyl acrylate, and methacrylic acid esters, such as cyclohexyl methacrylate, benzyl methacrylate, ethyl methacrylate, propyl methacrylate, or butyl methacrylate. The polymethyl methacrylate type resin is preferably produced by the continuous block polymerization technique. An example of such method is disclosed in Pat. No. 53-42260.

In addition, the core material may be made of a polymer comprising 98 wt% of monomer units mainly consisting of methacrylic

acid methyl and at least 2 wt% of ring-structured units represented by the following formula:



wherein R is an aliphatic cyclic hydrocarbon group, such as methyl, ethyl, propyl and the like.

To produce the optical fiber of the present invention, the sheath material is dissolved in a solvent, such as acetic acid ethyl, dimethyl formamide, or dimethyl acetamide, using the conventional method and coated over the surface of the core-forming fiber made of a quartz glass core wire or organic polymer by applying a soaking method. Another method is that, while performing the fiber-forming process with the core component polymer using a nozzle designed for fiber-forming a core-sheath complex, the sheath material is extrusion molded.

The optical fiber of the present invention can be utilized as a core-sheath structure without any modification, or a protection layer or coating layer made of an organic polymer may be combined if necessary. Furthermore, a tension member, such as polyester fiber, polyamide fiber, metallic fiber, carbon fiber, aromatic polyamide fiber, or synthetic aromatic polyester fiber, may be simultaneously applied to produce an optical fiber core wire, optical fiber cord, optical fiber cable, or the like.

[Operational Effectiveness]

The present invention provides a technique of forming the sheath part of an optical fiber using a specifically structured polymer. In this case, when fluoro alkyl methacrylate, methacrylic acid methyl, and methacrylic acid ester having cyclic hydrocarbon groups in the ester portion are polymerized by arranging the amounts satisfying an appropriate ratio, particularly a relative ratio for composing an azotropic polymer, and prepared polymer is applied as the sheath material, the produced optical fiber can provide significantly improved transparency, winding resilience, processibility, and heat resistance.

Hereinafter, the embodiments of the present invention will be explained.

Operational Example 1:

Monomers comprising 15% of methacrylic acid tricyclo [5,2,1,0^{2,6}]-deca-8-yl, 20% of methacrylic acid 2,2,2-trifluoroethyl, 60% of 1,1,2,2-tetrahydro perfluorodecyl, and 5% of methacrylic acid methyl were prepared, to which 0.05% of n-dodecyl mercaptan and 0.10% of 2,2'-azobis (isobutyronitril) were added to form a monomer mixture in an oxygen-absent atmosphere and polymerized in a reaction vessel maintained at 70°C, for 8 hours. Next, the reacted product was further polymerized at 120°C for 2 hours. The obtained monomer provided the following characteristics: Refraction factor $n_D^{25} = 1.405$; glass transfer temperature $T_g = 95^\circ\text{C}$; and MFR (230°C, 5 Kg f

22.8). Then, plastic optical fibers were formed using this polymer as a sheath part and polymethacrylic acid methyl as a core part.

The photo transmission loss of this optical fiber was 75 dB/Km at 570 nm, and 140 dB/Km at 650 nm. After heat-treating the fiber at 100°C for 24 hours, the photo transmission loss of the fiber was 80 dB/Km at 570 nm, and 150 dB/Km at 650 nm.

To examine the winding resilience, a 10 m long fiber was repeatedly wound around a rod (diameter = 1 cm) to observe the variation of light transmission quantity (winding test). As a result, after winding 100 times, the reduction of light transmission was limited to approx. 50%.

Operational Examples 2 - 8:

After the monomer composition used to provide a sheath part was modified as shown in Table 1, the same polymerization operation described in the operational example 1 was performed to produce a polymer of each example. This sheath-part polymer and core materials modified as shown in the table were processed to form fibers. The characteristics of produced fibers are shown in Part B of Table 1.

Table 1 (Part A):

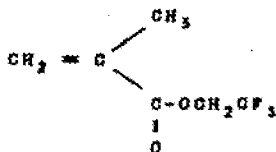
Operational example	Sheath component polymer			
	Element monomer and composition (wt%)	MFR (230°C 5Kg f)	Refraction Factor n _D ^{25°C}	Tg (°C)
2	Methacrylic acid tricyclo [5,2,1,0 ^{2,6}]-deca-8-il: 3FM: 17FM: MMA = 15:40:40:5	20.0	1.414	101
3	Methacrylic acid adamantyl: 3FM: 17FM: MMA = 5:30:50:15	19.2	1.410	91
4	Methacrylic acid bornyl: 3FM: 17FM: MMA = 25:25:45:5	19.0	1.415	103
5	Methacrylic acid 3,5-dimethyl-adamantyl: 3FM: 17FM: MMA = 15:30:50:5	18.9	1.411	99
6	Methacrylic acid tricyclo [5,2,1,0 ^{2,6}]-deca-8-il: 3FM: 17FM: MMA = 15:30:50:5	19.2	1.410	98
7	Methacrylic acid tricyclo [5,2,1,0 ^{2,6}]-deca-8-il: 3FM: 17FM: MMA = 30:20:50	20.0	1.420	108

Table 1 (Part B):

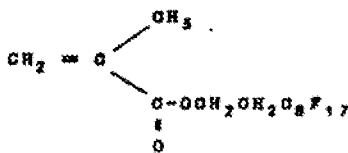
Operational example	Core component polymer		Transmission Loss (dB/Km)	
	Polymer type	Refraction ratio	Room temperature	After heat processing (100°C, 24 hours)
2	Polymethacrylic acid methyl	1.493	80 (570 nm) 145 (650 nm)	90 (570 nm) 160 (650 nm)
3	Polymethacrylic acid methyl	1.493	80 (570 nm) 150 (650 nm)	90 (570 nm) 170 (650 nm)
4	Polymethacrylic acid methyl	1.493	85 (570 nm) 152 (650 nm)	95 (570 nm) 182 (650 nm)
5	Polycarbonate	1.585	720 (770 nm)	725 (770 nm)
6	PMI	1.530	750 (650 nm)	750 (650 nm)
7	"	1.530	800 (650 nm)	800 (650 nm)

The winding test results were all excellent.

In Table 1, 3 FM denotes the polymer of:



17 FM denotes the polymer of:



PMI represents the N-methyl methacrylic imide - methacrylic acid methyl (composition ratio 4 : 6).

Comparison Example 1:

Using the same polymerization method described in the operational example 1, monomers comprising 20% of methacrylic acid 2,2,2-trifluoroethyl, 60% of 1,1,2,2-tetrahydro perfluorodecyl, and 20% of methacrylic acid methyl were prepared and made into a sheath-forming polymer. This sheath component and core component consisting of polymethacrylic acid methyl were processed by applying a complex fiber-forming method so as to prepare plastic optical fibers. The prepared monomer provided the following characteristics: Refraction factor $n_D^{25} = 1.405$; $T_g = 77^\circ\text{C}$. The photo transmission loss of the obtained fiber was 83 dB/Km at 570 nm, and 153 dB/Km at 650 nm. In addition, after heat-treating the fiber at 100°C for 24

hours, the photo transmission losses were measured for respective frequency areas. The test result in each frequency exceeded 1000 dB/Km. The winding test showed approx. 50% of optical transmission reduction after 100 times of winding processes.

Comparison Example 2:

Using the same polymerization operation described in the operational example 1, monomers comprising 80% of methacrylic acid 2,2,2-trifluoroethyl and 20% of methacrylic acid methyl were prepared and made into a sheath-forming polymer. This sheath component and core component consisting of polymethacrylic acid methyl were processed by applying a complex fiber-forming method so as to prepare plastic optical fibers. The prepared monomer had the following characteristics: Refraction factor $n_D^{25} = 1.435$; $T_g = 98^\circ\text{C}$. The photo transmission loss of the obtained fiber was 90 dB/Km at 570 nm, and 160 dB/Km at 650 nm. In addition, after heat-treating the fiber at 100°C for 24 hours, the photo transmission losses of the respective frequency areas were measured. The results exceeded 1000 dB/Km in both frequencies. Also, after 10 times of winding tests, light could not pass the fiber.